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Modified maxillomandibular advancement for obstructive sleep apnoea: towards a better outcome for Asians

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Abstract. Excluding tracheostomy, maxillomandibular advancement (MMA) is the most effective surgical treatment for obstructive sleep apnoea (OSA). However, the anticipated facial changes may prevent acceptance of this procedure by patients with bimaxillary protrusion, a common feature of Asian faces. We therefore developed a modified MMA technique for such cases, consisting of anterior segmental osteotomies together with standard Le Fort I and bilateral sagittal split osteotomies. A prospective study of 20 consecutive Taiwanese adults with moderate-to-severe OSA who underwent modified MMA and postsurgical orthodontics was undertaken to evaluate the efficacy with regard to OSA and the postoperative facial appearance and dental occlusion. After modified MMA, the mean apnoea–hypopnoea index decreased from 41.6 ± 19.2 n/h to 5.3 ± 4.0 n/h ($P < 0.001$). All patients had a successful outcome. No patient was dissatisfied with their postoperative facial appearance. The mean Peer Assessment Rating score decreased from 21.9 ± 14.3 to 1.7 ± 1.6 ($P = 0.001$). The data suggest that the modified MMA is effective in treating patients with moderate-to-severe OSA without negatively affecting facial appearance or dental occlusion. To achieve a better outcome, surgical–orthodontic integration is warranted. The surgery-first approach can achieve early improvement.

Key words: bimaxillary protrusion; orthognathic surgery; sleep apnoea; segmental osteotomy.

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Obstructive sleep apnoea (OSA) is a common disorder characterized by abnormalities in pharyngeal anatomy and physiology.[1] Currently, nasal continuous positive airway pressure (CPAP), which acts as a pneumatic splint within the upper airway, is the first line of treatment for OSA, especially in moderate-to-severe cases.[2] However, not all patients are compliant with the required lifetime nightly use, primarily because of intolerance. Furthermore, even in compliant patients who are using CPAP on a 'regular basis', the actual usage is only approximately 50% of the ideal.[3] Thus, surgery may be considered for OSA patients when other non-invasive treatments have been unsuccessful, in those who are intolerant or who

have been rejected on a long-term basis and desire surgery, and when the patient is medically stable and able to undergo the procedure.

Surgical interventions for OSA include several procedures, each designed to increase the patency of the upper airway at a specific level. Although many surgical procedures have been reported,[4] maxillomandibular advancement (MMA) is the most effective surgical treatment for OSA (excluding tracheostomy), with success rates between 75% and 100%.[5–9]

MMA traditionally consists of bilateral sagittal split osteotomies of the mandible and a Le Fort I osteotomy of the maxilla. MMA generally involves 10–12 mm maxillomandibular advancement.[10] However, it is important to achieve maximal advancement while maintaining a balanced facial appearance and functional dental occlusion. Interestingly, although many patients may be left with bimaxillary protrusion after such advancement surgeries, very few patients are dissatisfied with their appearance.[10] This can be explained in part by the fact that all surgeries reported have been done on Caucasian patients. Subjecting Asian patients to MMA for OSA usually results in aesthetic problems[11] because the majority of them have a flat nose, bimaxillary protrusion, and a weak chin before surgery (Fig. 1). This situation led us to develop a modified MMA technique, which comprises anterior segmental osteotomies together with standard Le Fort I and bilateral sagittal split osteotomies. We aimed to evaluate the efficacy of this modified MMA approach as a treatment for OSA and the resulting changes in facial appearance and dental occlusion.

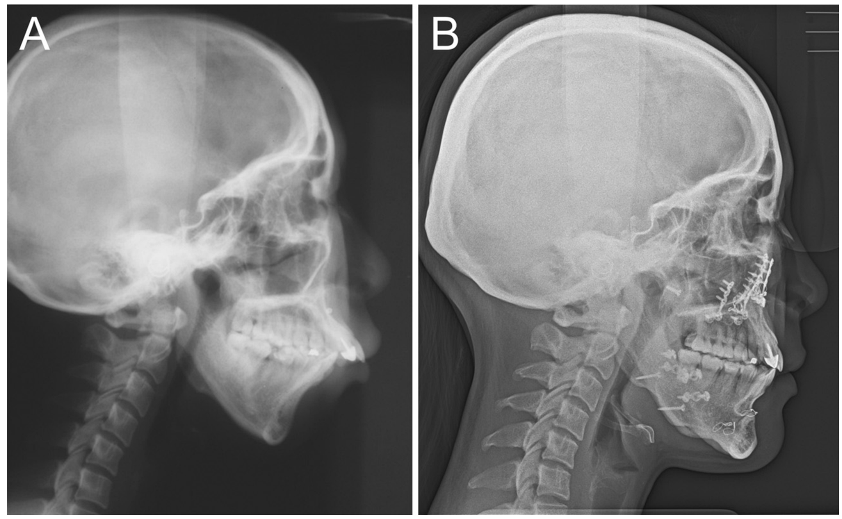

Fig. 1. (A) Preoperative and (B) postoperative cephalometric radiographs demonstrating significant improvement in pharyngeal airway, facial profile, and dental occlusion after modified MMA (i.e., Le Fort I segmental osteotomy, bilateral sagittal split osteotomy, and reversed-T mandibular osteotomy with counter-clockwise rotation). Note the screw for fixation of an unexpected fracture of the pterygoid plate.

Methods

Participants

Twenty men and women aged >18 years were enrolled in the study. The patients were recruited from a sleep centre between 2007 and 2011. Symptomatic Taiwanese adults with at least moderate-to-severe OSA (i.e., an apnoea–hypopnoea index (AHI) $\geq$15 n/h) for whom other conservative treatments (e.g., CPAP, weight loss, or oral appliance) or prior surgical procedures were unsuccessful, who were intolerant, or refused on a long-term basis, who desired surgery, and who were medically stable enough to undergo the surgical procedure were eligible for participation. Exclusion criteria included genetic syndromes, significant psychological disease, and an inability to comply with the scheduled follow-up evaluations.

After enrolment in the study, participants were scheduled for three baseline assessments. The assessments were conducted on separate days and consisted of (1) a single night of laboratory polysomnography (PSG) (baseline); (2) a physical assessment at which the upper airway was assessed and the medical history was taken; (3) a dental study cast assessment, from which dental occlusion was determined; and (4) a cephalometric radiograph assessment to screen for abnormal craniofacial and upper airway morphology.

Once baseline assessments were complete, participants were scheduled for a surgery-first modified MMA (i.e., no presurgical orthodontics). Following surgery, participants completed the same assessments as at baseline. In addition, they were asked to rate satisfaction with their postoperative facial appearance on 5-point Likert scales (1 = very dissatisfied; 5 = very satisfied) and whether they would recommend the same treatment to other patients. The study was approved by the hospital institutional review board.

Treatments

Modified MMA

Before surgery, a single surgical splint was fabricated by a single experienced orthodontist for the alignment of the mobilized dental segments during surgery.

Surgeries were performed with hypotensive general anaesthesia. Bilateral sagittal split mandibular osteotomies were executed first. Maxillary osteotomies (Le Fort I osteotomy with/without segmentation) (Fig. 2) were then performed, followed by intermaxillary wiring, forward

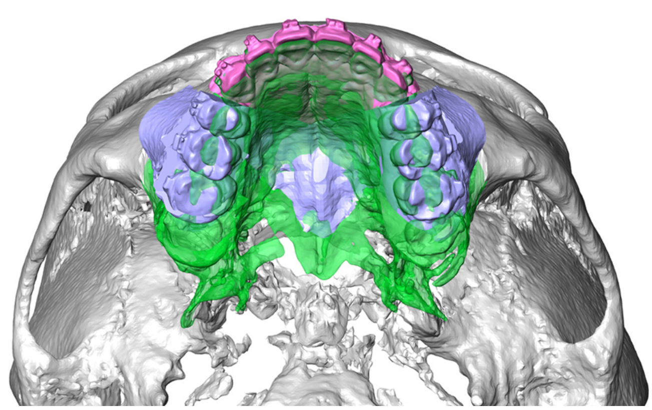

Fig. 2. Three-dimensional virtual model showing preoperative (green) and immediately postoperative (pink = anterior segment, blue = posterior segment) occlusal view of Le Fort I segmental osteotomies involving extraction of bilateral first premolars.

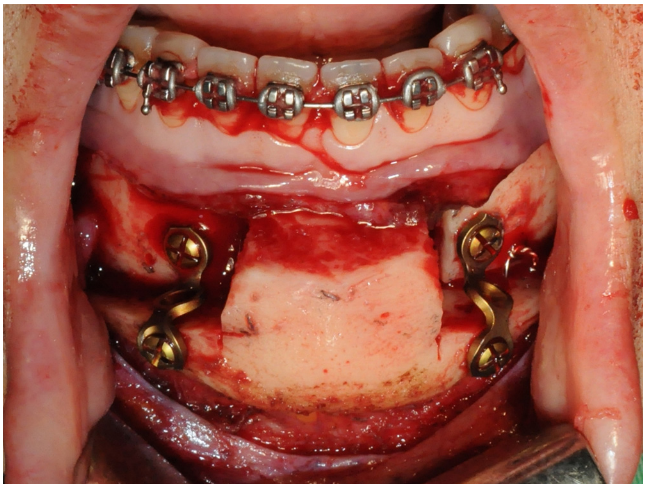

Fig. 3. Intraoperative view of the reversed-T mandibular osteotomy involving an overriding advancement of the osteotomized segment.

repositioning with/without counter-clockwise rotation of the maxillomandibular complex (MMC), and rigid fixation. If indicated, a reversed-T mandibular osteotomy (RTMO) was also performed. The RTMO comprises a combination of genioglossus advancement and advancing genioplasty in one piece.[8] This involves an overriding advancement of the osteotomized segment (Fig. 3).

After surgery and immediately before recovery from anaesthesia, the intermaxillary wiring was released for dental occlusion check and to allow for safer airway care.

Postsurgical orthodontics

The goals of postsurgical orthodontics in the surgery-first modified MMA are to decompensate the malocclusion, detail the dental occlusion, and ensure skeletal stability. This usually takes longer than 6 months.

One month before surgery, 0.022-inch preadjusted brackets were bonded. Cephalometric prediction and model surgery were next performed to finalize the surgical plan and fabricate the surgical splint. In order to maximize airway enlargement, the mandibular advancement was at least 10–12 mm. As surgery is performed first, molars are the guide to anteroposterior jaw positioning.[12] To ensure there was no problem in fitting a splint, 0.016-inch or 0.016 × 0.022-inch nickel–titanium archwires were not inserted until 1–2 days before surgery.

Postsurgical orthodontic treatment was initiated immediately after surgery because the active archwires (i.e., nickel–titanium archwires) were already in place, to take advantage of the unlocked occlusion and rapid tooth movement following surgery.[12] Alignment, levelling, and coordination were then begun. For cases receiving maxillary segmental surgery, the sectional archwires were replaced with continuous archwires at the first postsurgical orthodontic appointment. When there was an anterior open bite, light anterior vertical elastics were used to guide the jaw position. Once alignment, levelling, and coordination were achieved, 0.016 × 0.022-inch nickel–titanium archwires were replaced with 0.016 × 0.022-inch stainless steel archwires. Incomplete incisor decompensation could be assisted by class III elastics. By this time, postsurgical orthodontic finishing was much the same as with postsurgical orthodontics in classic surgical–orthodontic treatment.

Sleep measures

Polysomnography

PSG was performed at screening, baseline, and postsurgery, and was scored according to standard criteria.[13,14] The mean time interval between PSG at baseline and postsurgery was 14.0 ± 9.3 months (range 6–27 months).

Apnoea was defined by a cessation of airflow for at least 10 s in association with oxygen desaturation of at least 3% or an arousal. Hypopnoea was defined by a reduction in the amplitude of airflow, as measured using nasal pressure or thoracoabdominal wall movement, by >50% of the baseline measurement for >10 s, in association with oxygen desaturation of at least 3% or an arousal. The AHI was defined as the combined number of apnoeic and hypopnoeic events per hour (n/h) of total sleep time, and the desaturation index (DI) as the number of desaturation (4%) episodes per hour of total sleep time. Each patient's age, sex, height, and weight were also recorded.

Subjective sleepiness

The Epworth Sleepiness Scale (ESS)[15] was administered at baseline and postsurgery prior to PSG to assess subjective sleep quality over the previous 4 weeks.

Craniofacial and upper airway measures

Physical examination

A physical examination of three segments of the upper airway was performed: rhinopharynx, velopharynx, and oropharynx. An examination of the nasal cavity was done to identify septal deviation and turbinate hypertrophy. The oral cavity was examined to identify a long soft palate, hypertrophic tonsils (grade III or IV), and oropharyngeal obstruction from the base of the tongue (Mallampati grade III or IV). A single investigator performed all examinations.

Cephalometry

The craniofacial and upper airway morphology was determined with lateral cephalometric radiographs at baseline and post treatment (i.e., orthodontic debonding). Radiographs were taken with the patient awake. Briefly, patients were seated with the soft tissue Frankfort plane parallel to the floor, with the teeth in centric occlusion, and at end-expiration phase.

All radiographs were hand-traced by a single experienced orthodontist who was blinded to the patient's apnoea status. Craniofacial measures included sella–nasion–A point (SNA), sella–nasion–B point (SNB), A point–nasion–B point (ANB) and sella–nasion/mandibular plane (SN–MP) angles. Upper airway measures included soft palate length, minimal velopharyngeal airway (MinVP; distance measurement of the airway behind the soft palate perpendicular to the posterior pharyngeal wall), and minimal oropharyngeal airway (MinOP; distance measurement of the airway behind the tongue perpendicular to the posterior pharyngeal wall).

Dental occlusion measures

Assessment of the dental occlusal outcome was conducted with dental study casts taken at baseline and post treatment (i.e., orthodontic debonding). The occlusal

outcome can be assessed in many ways, but one of the most recognized is the Peer Assessment Rating (PAR), which provides a validated numeric score based on several occlusal features before and after treatment.[16,17] A PAR score of 0 indicates good alignment, and higher scores indicate high levels of malalignment. The difference in these scores gives an indication of improvement in treatment.

A single calibrated investigator who was blinded to the patient's previous treatment history scored the casts. Intra-examiner reliability was determined by a duplicate scoring of 10 randomly selected patients (five at baseline and five post treatment) after a 1-month interval by the same investigator. Intra-examiner reliability, evaluated using the intra-class correlation coefficient, was excellent (intra-class correlation coefficient 0.96, 95% confidence interval 0.94–0.98).

Statistical analysis

All statistical analyses were performed using SPSS version 17.0 software (SPSS Inc., Chicago IL, USA). Wilcoxon signed rank tests were used to compare the difference before and after surgery. Unless otherwise specified, data are presented as the mean ± standard deviation. All tests were two-tailed, with statistical significance set at $P < 0.05$.

Results

Patient characteristics

Patient characteristics are summarized in Table 1. Four of the 20 patients had been treated previously but had since voluntarily discontinued treatment. Two had undergone unsuccessful uvulopalatopharyngoplasty (UPPP) and two had discontinued oral appliance use.

A significant nasal obstruction associated with septal deviation was found in four patients and led to an additional septoplasty and turbinate reduction during the surgery. A long soft palate was present in all but three patients (two with prior UPPP). Hypertrophic tonsils (grade III or IV) were not encountered in any of the patients. Oropharyngeal obstruction from the base of the tongue (Mallampati grade III or IV) was clinically considered as significant in 19 (95%) patients. Regarding cephalometry, all but one patient demonstrated mandibular retrognathia (SNB <78°), 15 demonstrated a hyperdivergent facial type (SN–MP >37°), 18 demonstrated velopharyngeal narrowing (MinVP <9 mm), and 17 demonstrated oropharyngeal narrowing (MinOP <9 mm). Six patients had previously received orthodontic treatment with extraction of two premolars for upper lip or maxillary protrusion and thus underwent anterior segmental osteotomies in the mandible only (i.e., RTMO). Although the majority of patients lost some body weight initially after surgery, at the postoperative PSG, the body mass index (BMI) had returned to baseline ($P = 0.981$).

Table 1. Participant characteristics ($N = 20$).

Age, years, mean ± SD (range)	33.4 ± 6.5 (25–48)
Sex, *n* (%)	
Male	17 (85)
Female	3 (15)
BMI, kg/m^2, mean ± SD (range)	22.4 (3.4) (17–28)
Severe OSA[a], *n* (%)	12 (60)
Sagittal skeletal type[b], *n* (%)	
Class I	1 (5)
Class II	19 (95)
Class III	0 (0)
Vertical skeletal type[c], *n* (%)	
Hypodivergent	0 (0)
Normally divergent	5 (25)
Hyperdivergent	15 (75)
Previous OSA treatment, *n* (%)	4 (20)
With concomitant nasal surgery, *n* (%)	4 (20)
With maxilla segments, *n* (%)	14 (70)
With mandible segments, *n* (%)	17 (85)
With counter-clockwise rotation of MMC, *n* (%)	12 (60)
Treatment duration, months, mean ± SD (range)	15.3 (5.1) (8–26)

SD, standard deviation; BMI, body mass index; OSA, obstructive sleep apnoea; MMC, maxillomandibular complex; AHI, apnoea–hypopnoea index; ANB, A point–nasion–B point; SN–MP, sella–nasion/mandibular plane angle.
[a] AHI >30 *n*/h.
[b] Class I: ANB 0–4°; class II: ANB >4°; class III: ANB <0°.
[c] Hypodivergent: SN–MP <28°; normally divergent: SN–MP 28–37°; hyperdivergent: SN–MP >37°.

Treatment effectiveness

Modified MMA was highly effective resulting in a significant improvement in AHI, sleep, and oximetry parameters (Table 2). The success rate was 100% according to the criteria of a >50% improvement in AHI as well as post-treatment AHI <15 *n*/h.

Satisfaction

Seventeen (85%) patients were 'satisfied' or 'very satisfied' with their postoperative facial appearance. None of the patients graded their face as worse than before surgery (Table 3). All patients would recommend the same treatment to others.

Dental occlusal outcome

The PAR score decreased significantly after treatment (Table 3) and the mean percentage PAR reduction was 84.7 ± 18.6%.

Table 2. Modified maxillomandibular advancement: polysomnography results.[a]

	Baseline	Postsurgery	*P*-value
AHI, *n*/h	41.6 ± 19.2	5.3 ± 4.0	<0.001
AI, *n*/h	27.1 ± 20.7	0.4 ± 1.2	<0.001
HI, *n*/h	14.4 ± 10.3	4.8 ± 3.7	0.001
DI, *n*/h	31.7 ± 25.6	2.2 ± 2.4	<0.001
Mean SpO_2, %	94.7 ± 2.8	96.2 ± 1.2	0.012
Minimum SpO_2, %	80.2 ± 9.7	88.9 ± 5.0	<0.001
Stage 1 + 2, % of TST	73.8 ± 9.7	66.7 ± 8.2	0.011
Stage 3 + 4, % of TST	9.6 ± 10.2	15.0 ± 10.9	0.079
REM, % of TST	11.9 ± 7.3	17.4 ± 7.6	0.005
ESS score	11.9 ± 3.5	7.0 ± 3.0	0.004

AHI, apnoea–hypopnoea index; AI, apnoea index; HI, hypopnoea index; DI, desaturation index; SpO_2, arterial oxygen saturation; TST, total sleep time; REM, rapid eye movement; ESS, Epworth sleepiness scale.
[a] Data are given as the mean ± standard deviation.

Table 3. Modified maxillomandibular advancement: facial appearance and dental occlusal results.

Facial appearance, *n* (%)	
Very dissatisfied	0 (0)
Dissatisfied	0 (0)
Neutral	3 (15)
Satisfied	7 (35)
Very satisfied	10 (50)
PAR score, mean ± SD	
Baseline	21.9 ± 14.3[a]
Post treatment	1.7 ± 1.6[a]

PAR, Peer Assessment Rating; SD, standard deviation.
[a] $P = 0.001$.

Discussion

The modified MMA technique consists of anterior segmental osteotomies together with the standard Le Fort I and bilateral sagittal split osteotomies. The anterior segmental osteotomies can be added in the maxilla, mandible, or both, as indicated. There are several functional and aesthetic rationales for the addition of anterior segmental osteotomies in the modified MMA. First, the modified MMA technique still allows the upper airway to be enlarged due to pulling forward of the anterior pharyngeal tissues attached to the posterior maxilla, mandible, and hyoid bone.[18] Second, the segmental Le Fort I osteotomy can minimize the upper lip or maxillary protrusion commonly encountered in Asian patients who have undergone a classic MMA, by setting back of the anterior maxilla, usually following extraction of two premolars or using existing edentulous spaces (Figs. 1 and 2). Third, the segmental Le Fort I osteotomy can coordinate the dental arch simultaneously. In a classic MMA, a bilateral posterior crossbite often occurs in class II malocclusion because the mandibular arch is advanced into a narrower maxillary arch. By larger advancement of the posterior segment compared with the anterior segment from the segmental Le Fort I osteotomy, such crossbite can often disappear (Fig. 2). This segmental Le Fort I osteotomy is also favourable to OSA improvement, as a narrow maxillary arch is a risk factor for OSA.[19–21] Finally, the RTMO allows for additional advancement of the genial tubercle with attached genioglossus muscle. The procedures can increase tension on the genioglossus muscle, preventing the tongue from posterior drop during sleep. This is indicated for patients with retrogenia following mandibular advancement; i.e., the RTMO can minimize the weak chin commonly encountered in Asian patients who have undergone a classic MMA, by advancing the chin (Fig. 1).

The design of the counter-clockwise rotation of the MMC in the modified MMA for selected cases also has functional and aesthetic rationales. The design is often used in high mandibular plane angle patients. The counter-clockwise rotation can improve the facial profile by larger advancement of the mandible (e.g., chin) than the maxilla (e.g., base of the nose) (Fig. 1).[22,23] It can also maximize oropharyngeal airway enlargement through adequate basal mandibular advancement in the horizontal dimension.[22–24]

For aesthetic reasons, Goh and Lim[25] modified the classic MMA with the addition of anterior sub-apical osteotomies in both the maxilla and mandible. Their intention was to minimize the postoperative bimaxillary protrusion after a classic MMA by setting back the anterior maxilla and anterior alveolar ridge of the mandible. However, the anterior mandibular sub-apical osteotomy is usually associated with backward movement of the genial tubercle with attached genioglossus muscle, which is detrimental to OSA improvement. It is also technically difficult to perform RTMO together with this anterior sub-apical osteotomy.

The modified MMA procedure requires surgical–orthodontic integration. The orthodontic integration in the modified MMA has several functional rationales. First, the orthodontics allow correction of postsurgical malocclusion. Postsurgical malocclusion was not uncommon in our patients since the majority of them had not received orthodontic treatment before. Second, the orthodontics can minimize postsurgical malocclusion owing to skeletal relapse from a large advancement or a counter-clockwise rotational advancement. Although arch bars have been used routinely instead of orthodontics to establish occlusion in other centres, postsurgical malocclusion is still unavoidable. Finally, the orthodontics can achieve complete skeletal correction. This is especially true in skeletal class II deformity as the lower incisors have been proclined before surgery by compensatory adaptation.

The use of the surgery-first approach in the modified MMA has several functional rationales. First, the surgery-first approach allows early improvement of OSA owing to minimal presurgical orthodontic preparation. Second, the surgery-first approach reduces the risk of OSA worsening from presurgical orthodontic preparation. This is especially true in class II malocclusion.[26] In a classic orthognathic case, incisor decompensation (i.e., retraction of the lower incisors) should be performed before surgery in order to achieve complete skeletal correction, as the incisors are the guide for anteroposterior jaw position. This inevitably causes mandibular arch constriction, leading to narrowing of the oral space,[27] which may risk OSA worsening. Taken together, the surgery-first approach is a function-first approach.

In conclusion, this study shows that the modified MMA is effective in treating patients with moderate-to-severe OSA without negatively affecting facial appearance and dental occlusion. To achieve a better outcome, surgical–orthodontic integration is warranted. The surgery-first approach can achieve early improvement.

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Competing interests

None declared.

Ethical approval

Chang Gung Memorial Hospital.

Patient consent

Not required.

References

1. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993;**32**:1230–5.
2. Giles TL, Lasserson TJ, Smith BH, White J, Wright J, Cates CJ. Continuous positive airways pressure for obstructive sleep apnoea in adults. *Cochrane Database Syst Rev* 2006;**3**:CD001106.
3. Grote L, Hendner J, Grunstein R, Kraiczi H. Therapy with nCPAP: incomplete elimination of sleep related breathing disorder. *Eur Respir J* 2000;**16**:921–7.
4. Sher AE, Schechtman KB, Piccirillo JF. The efficacy of surgical modifications of upper airway in adults with obstructive sleep apnea syndrome. *Sleep* 1996;**19**:156–77.
5. Waite PD, Wooten V, Lachner J, Guyette RF. Maxillomandibular advancement surgery in 23 patients with obstructive sleep apnea syndrome. *J Oral Maxillofac Surg* 1989;**47**:1256–61.
6. Riley RW, Powell NB, Guilleminault C. Obstructive sleep apnea syndrome: a review of 306 consecutively treated surgical patients. *Otolaryngol Head Neck Surg* 1993;**108**:117–25.

7. Hochban W, Brandenburg U, Peter JH. Surgical treatment of obstructive sleep apnea by maxillomandibular advancement. *Sleep* 1994;**17**:624–9.
8. Prinsell JR. Maxillomandibular advancement surgery in a site-specific treatment approach for obstructive sleep apnea in 50 consecutive patients. *Chest* 1999;**116**:1519–29.
9. Bettega G, Pepin JL, Veale D, Deschaux C, Raphael B, Levy P. Obstructive sleep apnea: fifty-one consecutive patients treated by maxillofacial surgery. *Am J Respir Crit Care Med* 2000;**162**:641–9.
10. Li KK. Surgical therapy for adult obstructive sleep apnea. *Sleep Med Rev* 2005;**9**:201–9.
11. Li KK. Maxillomandibular advancement for obstructive sleep apnea. *J Oral Maxillofac Surg* 2011;**69**:687–94.
12. Liao YF, Chiu YT, Huang CS, Ko EW, Chen YR. Presurgical orthodontics versus no presurgical orthodontics: treatment outcome of surgical–orthodontic correction for skeletal class III open bite. *Plast Reconstr Surg* 2010;**126**:2074–83.
13. Kushida CA, Littner MR, Morgenthaler T, Alessi CA, Bailey D, Coleman Jr J et al. Practice parameters for the indications for polysomnography and related procedures: an update for 2005. *Sleep* 2005;**28**:499–521.
14. Iber C, Ancoli-Israel S, Chesson A, Quan S. *AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications*. Westchester, IL: American Academy of Sleep Medicine; 2007.
15. Johns MW. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. *Sleep* 1991;**14**:540–5.
16. Richmond S, Shaw WC, Roberts CT, Andrews M. The PAR index (Peer Assessment Rating): methods to determine outcome of orthodontic treatment in terms of improvement and standards. *Eur J Orthod* 1992;**14**:180–7.
17. Richmond S, Shaw WC, O'Brien KD, Buchanan IB, Jones R, Stephens CD, et al. The development of the PAR index (Peer Assessment Rating): reliability and validity. *Eur J Orthod* 1992;**14**:125–39.
18. Hsieh YJ, Liao YF, Chen NH, Chen YR. Changes in the calibre of the upper airway and the surrounding structures after maxillomandibular advancement for obstructive sleep apnoea. *Br J Oral Maxillofac Surg* 2014;**52**:445–51.
19. Cistulli PA, Richards GN, Palmisano RG, Unger G, Sullivan CE. Influence of maxillary constriction on nasal resistance and sleep apnea severity in Marfan's syndrome. *Chest* 1996;**110**:1184–8.
20. Kushida CA, Efron B, Guilleminault C. A predictive morphometric model for the obstructive sleep apnea syndrome. *Ann Intern Med* 1997;**127**:581–7.
21. Seto BH, Gotsopoulos H, Sims MR, Cistulli PA. Maxillary morphology in obstructive sleep apnoea syndrome. *Eur J Orthod* 2001;**23**:703–14.
22. Wolford LM, Charemello PD, Hilliard F. Occlusal plane alteration in orthognathic surgery. Part I: Effects on function and aesthetics. *Am J Orthod Dentofacial Orthop* 1994;**106**:304–16.
23. Brevi BC, Toma L, Pau M, Sesenna E. Counterclockwise rotation of the occlusal plane in the treatment of obstructive sleep apnea syndrome. *J Oral Maxillofac Surg* 2011;**69**:917–23.
24. Goncalves JR, Buschang PH, Goncalves DG, Wolford LM. Postsurgical stability of oropharyngeal airway changes following counter-clockwise maxillo-mandibular advancement surgery. *J Oral Maxillofac Surg* 2006;**64**:755–62.
25. Goh YH, Lim KA. Modified maxillomandibular advancement for the treatment of obstructive sleep apnea: a preliminary report. *Laryngoscope* 2003;**113**:1577–82.
26. Yang YL, Liao YF, Hsieh YJ, Lin CH. An unreported risk in extraction orthodontic treatment in an adult with skeletal class II deformity: worsening of obstructive sleep apnea. *23rd Annual Meeting of Taiwan Association of Orthodontists*. 2011.
27. Wang Q, Jia P, Anderson NK, Wang L, Lin J. Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of class I bimaxillary protrusion. *Angle Orthod* 2012;**82**:115–21.

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